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LATERAL LOAD BEHAVIOUR OF INTERLOCKING BLOCK MASONRY WALL

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ABSTRACT

Masonry walls constructed using Interlocking Blocks, where no mortar is used for bonding of Blocks. The interface bonding of Interlocking blocks under lateral loads was studied in this paper, by modelling a 4’ × 4’ masonry wall. This masonry wall was analysed by assigning in-plane lateral load with varying magnitudes and compared the results with a conventional brick masonry wall. The individual dimension of each block of both types is given detailed in modelling. These models are analysed in Ansys 15.0 workbench module. Total Deformation, Equivalent stress (von - Mises), Equivalent elastic strain (von – Mises) and strain Energy was observed for both conventional brick masonry wall and Interlocking block masonry wall and hence Stress-Strain graphs and Load - Deformation graphs had been plotted. As a result, percentage variations had observed in terms of deformation at a specific load when compared with a conventional brick masonry wall.

Key words: Interface bonding, conventional bricks and interlocking blocks.

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1. INTRODUCTION

Masonry structures are the structures which are built by the conventional bricks and bonded with cement mortar. They are resistant to heat and they provide good protection against fire. The compressive strength of the brick is sufficient for ordinary constructions. The model of conventional brick is shown in Figure 1.

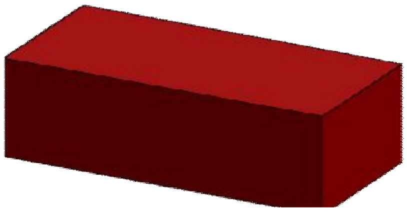

Figure 1 Conventional Brick

1.1. Interlocking Blocks

The blocks which are having interlocking patterns. Each brick has a projection at one side and a depression at the other. The projection of one brick fits into the depression of the next so that they always align precisely. Wall construction will be finished without using cement mortar for bonding purpose. The model of the interlocking block is shown in Figure 2.

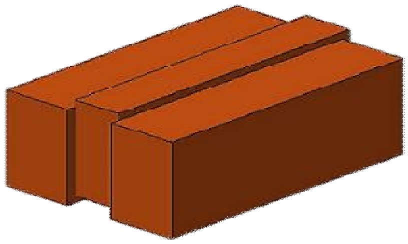

Figure 2 Interlocking Block

1.2. Stabilized Earthen Blocks

The raw materials used to manufacture compressed earthen blocks is moistened and poured into a press and then compressed either manually or hydraulically. These blocks can be compressed in different sizes and shapes. But nowadays these are much popular as Compressed Earthen Stabilised Blocks (CSEB) due to the addition of stabilizers commonly cement or lime. These stabilizers are used for better bonding purpose, compressive strength and water resistance. With cement stabilization, after manufacturing these blocks must be cured for four weeks. After curing and free drying these blocks can be used as conventional bricks.

2. MODELLING

Modelling plays a key role in any type of analysis. Modelling can be done in any analytical software or either can be done in CAD software. For this paper, all the modelling works are done in SolidWorks 2015. In SolidWorks 2015, various parts of the masonry wall are created part wise in the part-session and later these parts are assembled in the assembly session. All these parts are modelled in standard units i.e. centimetre (cm).

2.1. Conventional Brick Masonry Wall

Conventional brick is done with the standard dimensions of 19 × 9 × 9 cm (Length × Breadth × Height). Along with mortar, the standard dimension changes to 20 × 10 × 10 cm (Length × Breadth × Height). So, from this mortar should be of 1 cm in thickness. Horizontal mortar is made with the dimensions of 119 cm × 9 cm × 1 cm (Length × Breadth × Thickness) and vertical mortar is made with the dimensions of 9 cm × 9 cm × 1 cm (Length × Breadth × Thickness). With these dimensions, various parts of walls are modelled and as mentioned earlier all these parts are assembled in assembly session to form 4’ × 4’ wall. To arrange this dimensioned wall, a few half bricks has to be modelled with the dimensions of 9 cm × 9 cm ×

9 cm (Length × Breadth × Height). With these dimensions, 6 bricks are arranged in lengthwise as the bottom layer and 12 complete bricks are arranged height wise. The model of a conventional brick masonry wall is shown in Figure 3.

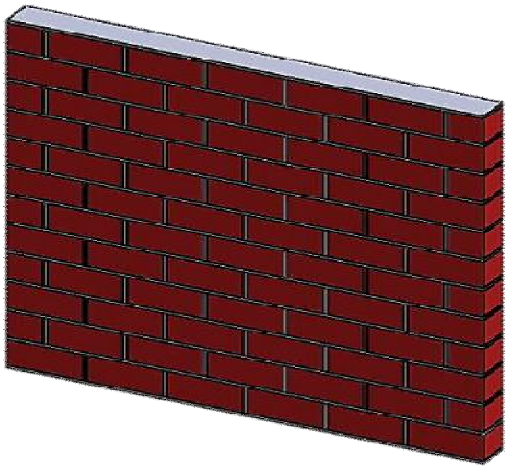

Figure 3 Conventional brick masonry wall

2.2. Interlocking Block Masonry Wall

The interlocking block is done with the dimensions of 30.48 × 20.32 × 13.97 cm (Length × Breadth × Height). Every Stabilised interlocking block has a pattern which has been divided into 3 volumes, in that middle volume of the brick has projections and depressions. Out of 3 volumes, the breadth of end volumes is completely different from the middle volume. The breadth of end volumes are made with 7.5 cm meanwhile, the middle volume is made with 5.32 cm. This pattern is meant for interlocking with each other. The dimension of projection and depression is made with 1 cm. With these dimensions, various parts of walls are modelled and as mentioned earlier, all these parts are assembled in assembly session to form 4' × 4' wall. To make this wall a few half bricks has to be modelled with the dimensions of 15.24 cm × 20.32 cm × 13.97 cm. (Length × Breadth × Height). With these dimensions, 4 bricks are arranged in lengthwise as the bottom layer and 8 complete bricks are arranged height wise. To arrange 4' height of the wall, a special brick has to be modelled with the dimension of 10.16 cm in height wise instead of 13.97 cm. The model of interlocking block masonry wall is shown in Figure 4.

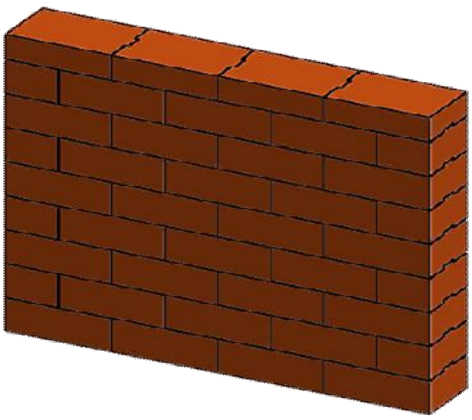

Figure 4 Interlocking block masonry wall

3. GEOMETRY

The models which are created in the CAD software should import for analysis to the analytical software. In this way, models which are done in SolidWorks 2015 are imported to Ansys 15.0 workbench. In order to import these models, all the models which are created in SolidWorks 2015 are then converted to IGES (.igs) format. These models are analysed by assigning desired properties which represent the material type. The various properties assigned for the material are as follows.

Table 1 Properties of Interlocking Blocks

Property	Value
Density (Kg/m^3)	2000
Coefficient of Thermal Expansion (C^{-1})	0.012
Young's Modulus (Pa)	8E+08
Poisson's Ratio	0.2
Tensile Ultimate Strength (Pa)	1.5E+06
Compressive Ultimate Strength (Pa)	6E+06
Isotropic Thermal Conductivity (W/mc)	0.5
Specific Heat (J/kgc)	850

Table 2 Properties of Conventional Bricks

Property	Value
Density (Kg/m^3)	1900
Coefficient of Thermal Expansion (C^{-1})	0.0000031
Young's Modulus (Pa)	4.22E+09
Poisson's Ratio	0.31
Compressive Ultimate Strength (Pa)	3.4323E+06
Isotropic Thermal Conductivity (W/mc)	0.6
Specific Heat (J/kgc)	900

Table 3 Properties of Cement Mortar

Property	Value
Density (Kg/m^3)	1470
Coefficient of Thermal Expansion (C^{-1})	0.0000041
Young's Modulus (Pa)	2.28E+09
Poisson's Ratio	0.29
Compressive Ultimate Strength (Pa)	2E+07
Isotropic Thermal Conductivity (W/mc)	0.52
Specific Heat (J/kgc)	703

4. ANALYTICAL STUDY

4.1. Modal Analysis

The analysis which is based on the study of the structural dynamic properties under excitation of vibrations is said to be Modal analysis. Whenever a body starts vibrating with greater amplitude, then that means the natural frequency of the body matches with the actuating frequency.

4.1.1. Mode Shapes

At a particular frequency, a mechanical system executes a vibrational pattern, then it is said to be a Mode shape. Various mode shapes will be generated by various frequencies. A conventional brick masonry wall and Interlocking block masonry wall underwent modal analysis individually. Mode shapes are formed at a specific frequency which is shown in a tabular column.

Table 4 Mode with Specific frequency for both types of walls

Mode	Frequency [Hz]	
	Conventional brick masonry wall	Interlocking block masonry wall
1	14.584	13.862
2	35.151	32.553
3	87.165	55.169
4	114.38	77.497
5	123.07	97.392
6	124.79	107.95
7	214.73	130.04
8	240.36	148.78
9	260.92	175.57
10	279.12	193.52

4.2. In-Plane Lateral Loading

As mentioned earlier, all the models are imported to ANSYS 15.0. Both types of walls are analysed individually with assigned in-plane lateral forces with various magnitudes i.e. 1 kN, 3.5 kN, 7.5 kN and 10.5 kN respectively. The bottom of the walls are considered as fixed and these in-plane lateral forces are assigned to the top brick of the wall of both types. Total Deformation, Equivalent stress (von - Mises), Equivalent elastic strain (von – Mises) and strain Energy was observed for various magnitudes of both types. Analytical study of the conventional brick masonry wall and interlocking block masonry wall with 10.5 kN is shown below and various magnitudes maximum results are tabulated in Table 7.

Table 5 Description of Conventional brick masonry wall with 10.5 kN load

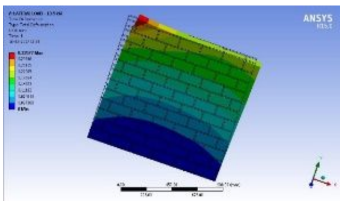

Figure 5 Total deformation

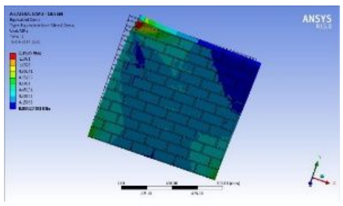

Figure 6 Equivalent stress

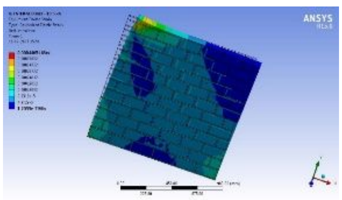

Figure 7 Equivalent elastic strain

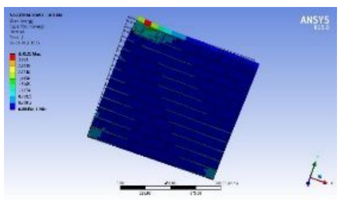

Figure 8 strain Energy

Table 6 Description of Interlocking block masonry wall with 10.5 kN load

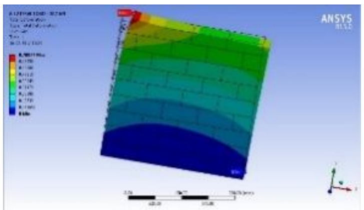

Figure 9 Total deformation

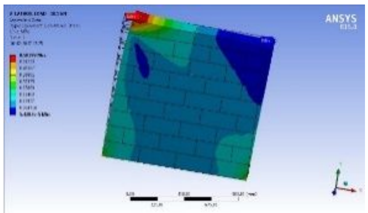

Figure 10 Equivalent stress

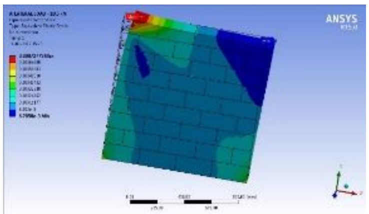

Figure 11 Equivalent elastic strain

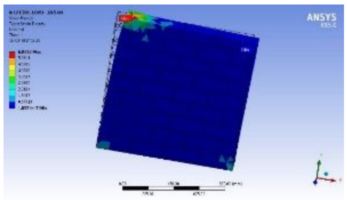

Figure 12 strain Energy

Table 7 Maximum result comparison between Conventional brick wall and Interlocking block wall

Parameters	Conventional brick masonry wall	Interlocking block masonry wall
Assigned In-plane lateral load by 1 kN		
Total deformation	0.031978 mm	0.067455 mm
Equivalent stress	0.1289 MPa	0.055428 MPa
Equivalent elastic strain	4.2525e-5	6.9308e-5
strain Energy	0.030949 mJ	0.054705 mJ
Assigned In-plane lateral load by 3.5 kN		
Total deformation	0.11192 mm	0.23609 mm
Equivalent stress	0.45116 MPa	0.194 MPa
Equivalent elastic strain	0.00014884	0.00024258
strain Energy	0.37913 mJ	0.67013 mJ
Assigned In-plane lateral load by 7.5 kN		
Total deformation	0.23984 mm	0.50591 mm
Equivalent stress	0.96677 MPa	0.41571 MPa
Equivalent elastic strain	0.00031894	0.00051981
strain Energy	1.7409 mJ	3.0771 mJ
Assigned In-plane lateral load by 10.5 kN		
Total deformation	0.33577 mm	0.70827 mm
Equivalent stress	1.3535 MPa	0.58199 MPa
Equivalent elastic strain	0.00044651	0.00072773
strain Energy	3.4121 mJ	6.0312 mJ

4.3. Contact Analysis

Whenever two different bodies touch each other that means they become mutually tangent, then they are said to be in contact with each other. Few characteristics will be applied in contact analysis which is as follows 1) Penetration is not possible. 2) Transmission of compressive normal forces is possible but transmission of tensile normal forces is not yet all

possible. 3) Transmission of tangential friction forces is possible. 4) They are not glued i.e. free to move and separate from each other.

In this paper, contact analysis is performed for a Conventional brick masonry wall and Interlocking block masonry wall. In ANSYS 15.0, to perform contact analysis, assigned contact type as bonded which has a property of no normal behaviour (separation) and no tangential behaviour (sliding) and behaviour as symmetric. The conventional brick masonry wall is made of bricks followed by mortar for bonding and interlocking block masonry wall which is made of pure interlocking blocks. These walls don't undergo penetration, separation and even sliding effect. Both types of walls are analysed individually with assigned lateral load 100 kN. The bottom of the walls are considered as fixed and this lateral load is assigned to the top brick of the wall of both types. Pressure, Penetration, Gap, Sliding distance and Frictional stress was observed for the applied load of both types. The following table shows the results of a Conventional brick masonry wall and Interlocking block masonry wall.

Table 8 Results of contact analysis for both masonry walls

Parameters	Conventional brick masonry wall	Interlocking block masonry wall
Pressure (MPa)	17.18	3.2562
Penetration (mm)	0.0011184	0.00092145
Gap (mm)	0	0
Sliding Distance (mm)	0.0009548	0.0019557
Frictional Stress (MPa)	10.9	3.5101
Pressure (MPa)	17.18	3.2562

The status of contact analysis for a Conventional brick masonry wall and Interlocking block masonry wall is shown in the following figures.

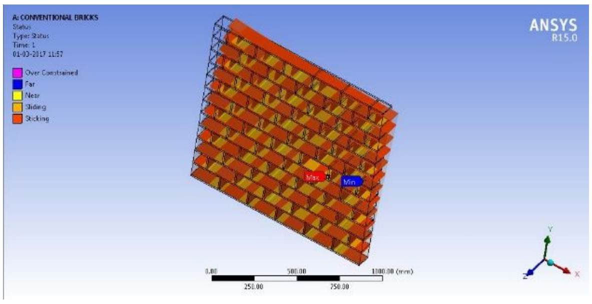

Figure 13 Contact status of Conventional brick masonry wall

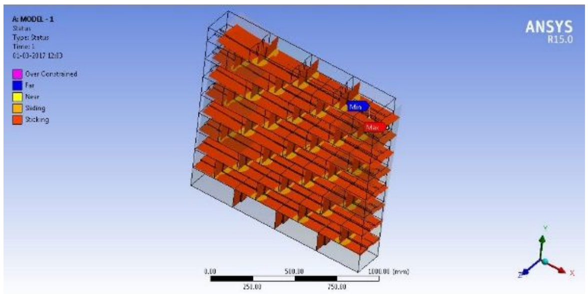

Figure 14 Contact status of Interlocking block masonry wall

5. RESULTS AND DISCUSSIONS

In this section, finite element analysis results of the masonry wall models are shown below. Stress – Strain graph, load – deformation graph and Mode – Frequency graph is discussed.

5.1. Stress – Strain Graph

There are two types of Stress – Strain graphs based on assigned in-plane lateral load for the analysed Conventional brick masonry wall and Interlocking block masonry wall. These graphs show a linear line. At a particular stress value, the line represents the corresponding strain value.

So, based on these loads, stress and strains are obtained. Loads are assigned in such a way that the interval between the loads is 500 N and the load value starts from 1000 N to 10500 N (1 kN to 10.5 kN).

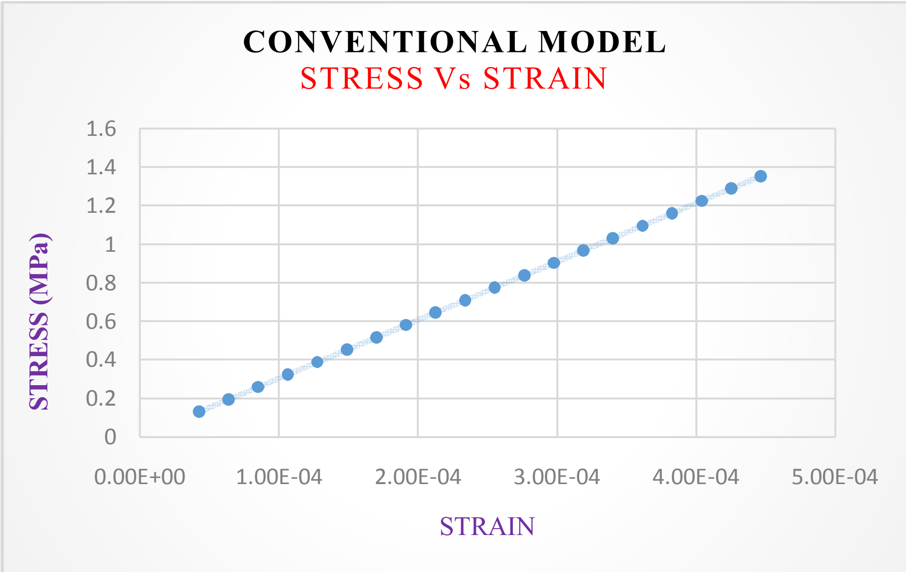

Figure 15 Stress – Strain graph for a conventional brick masonry wall.

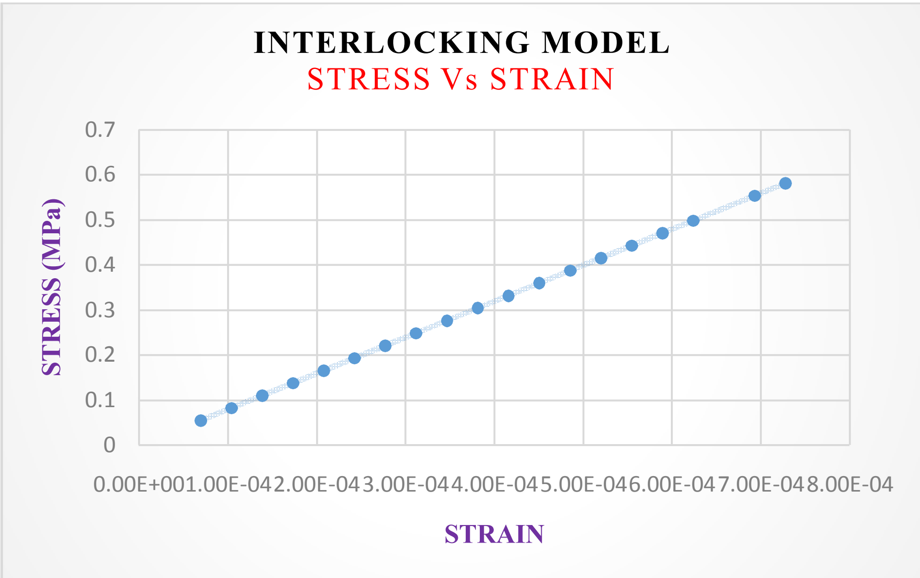

Figure 16 Stress – Strain graph for Interlocking block masonry wall.

5.2. Load -Deformation Graph

There are two types of Load -Deformation graphs based on assigned in-plane lateral load for the analysed Conventional brick masonry wall and Interlocking block masonry wall. These graphs show a linear line. At a particular load, the line represents the corresponding deformation. Loads are assigned in such a way that the interval between the loads is 500 N and the load value starts from 1000 N to 10500 N (1 kN to 10.5 kN).

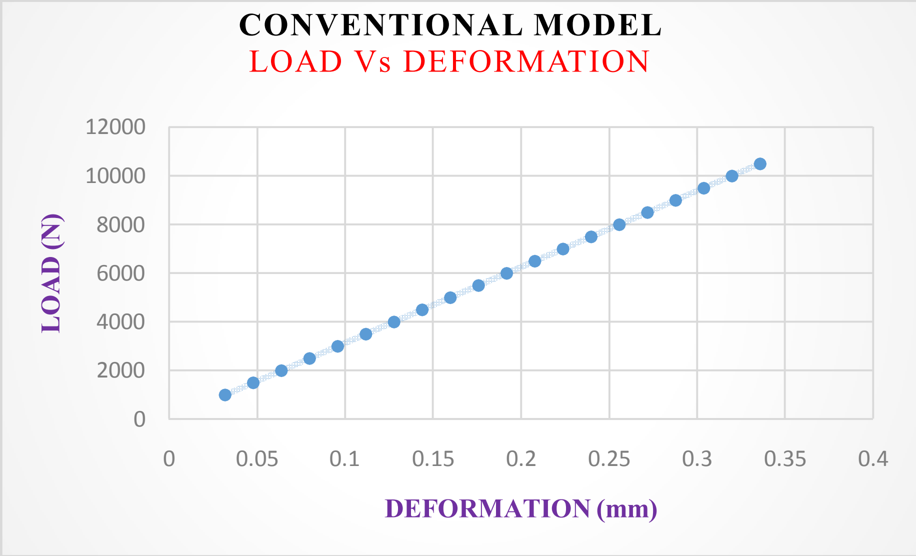

Figure 17 Load -Deformation graph for a conventional brick masonry wall.

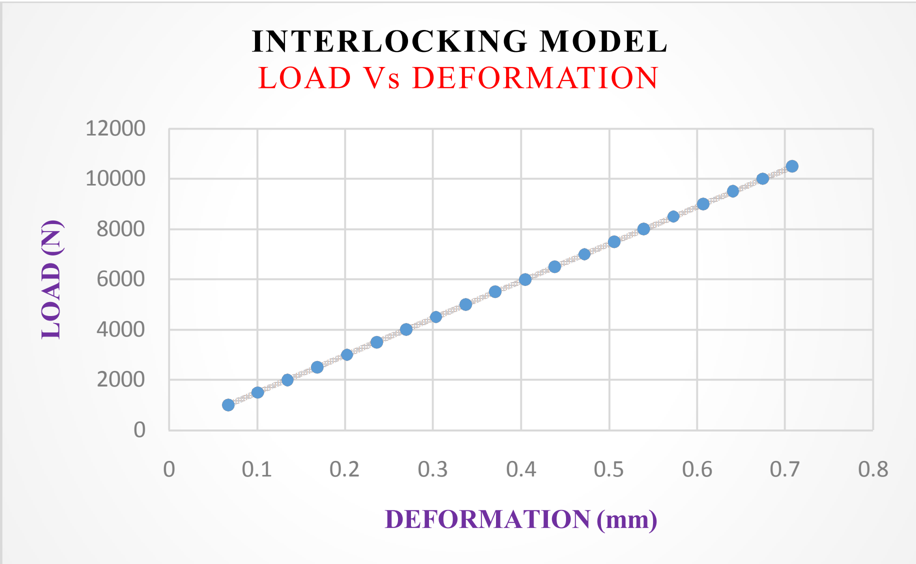

Figure 18 Load -Deformation graph for Interlocking block masonry wall.

5.3. Mode – Frequency Graph

There are two types of Mode – Frequency graphs obtained from the corresponding natural frequency for the analysed Conventional brick masonry wall and Interlocking block masonry wall. Various mode shapes will be generated by various frequencies that mean thefirst Mode is obtained from the first frequency in the same way the last mode is obtained from the last frequency.

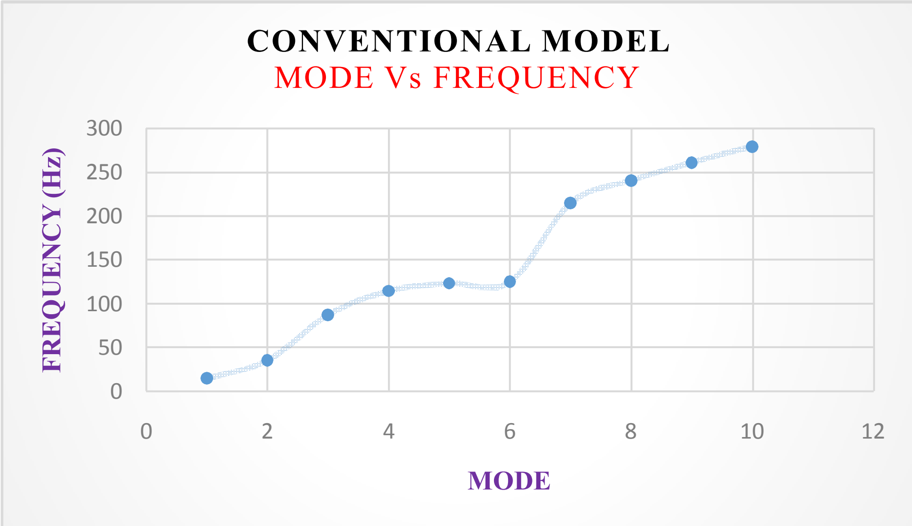

Figure 19 Mode – Frequency graph for a conventional brick masonry wall

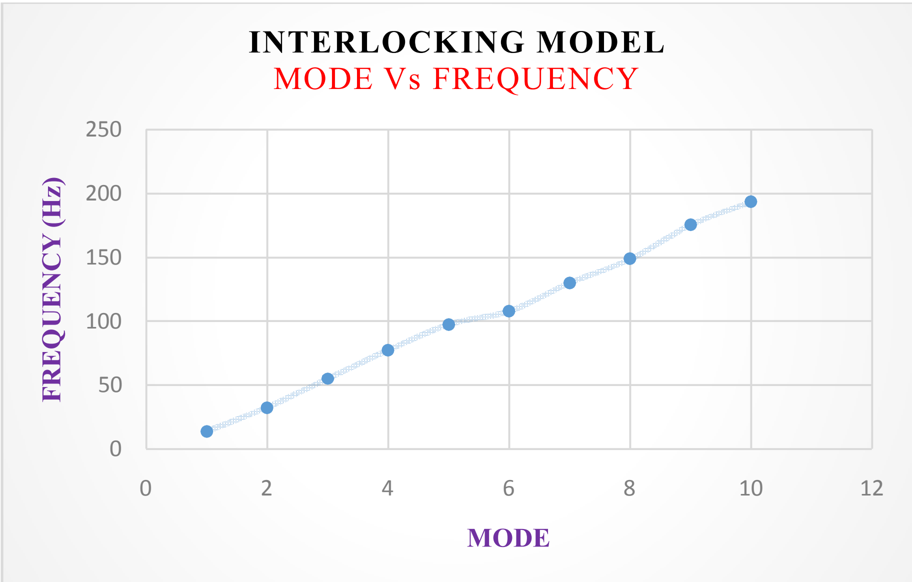

Figure 20 Mode – Frequency graph for Interlocking block masonry wall.

6. CONCLUSION

Masonry walls constructed using Interlocking blocks shows better performance compared to conventional bricks in terms of in-plane lateral loading. Conventional masonry walls are bonded with cement mortar whereas interlocking masonry walls are bonded by self-locking patterns. From the analytical study, the values obtained from the interlocking masonry walls are lesser compared with conventional masonry walls. 5% variations had observed in terms of deformation at a specific load when compared with a conventional brick masonry wall. Regarding contact analysis, the parameters such as penetration, gap, frictional stress and sliding distance values of interlocking masonry wall show improved performance compared with conventional masonry walls.

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